ASSESSMENT OF STUDENT LEARNING OUTCOMES AND EFFECTS ON PERCEPTIONS OF SCIENCE FROM INVOLVEMENT IN A HANDS-ON STEM OUTREACH EVENT

A Thesis
by
JORDAN LOLLAR ENGLISH

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Abstract

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This mixed methods study used a combination of preliminary/post assessments and student interviews to evaluate if participation in a hands-on outreach event by 98, 8th grade students from 6 public middle schools in the Southern Appalachian region, impacted their achievement of State Essential Standard derived learning outcomes and perceptions of science. Forty professional volunteers from government agencies, environmental nonprofits, professors, graduate students and pre-service teachers from a nearby college in the Southern Appalachian region, participated in the event. The average pre-assessment score was 56% and the average post-assessment score was 66%, revealing an increase of 10%. Student scores on the assessment increased by one letter grade from pre- to post-assessment. There was a statistically significant difference ($p < 0.0001$) between the pre-assessment and post-assessment scores. A difference was found in the pre-assessment scores between schools ($p < 0.0001$) and the post-assessment scores between schools ($p = 0.0002$). There was not a significant difference on student improvement on the assessment between the schools ($p = 0.1215$). Field observations and qualitative data from student interviews indicated that

participation in this environmental education outreach event allowed students an opportunity to connect content learned in the classroom with hands-on experiences, to improve achievement of learning outcomes and modest enhancement of positive perceptions of science. Results from three Likert Scale questions assessing perceptions of science did not reveal a statistically significant difference. Emerged best practices for implementing environmental education outreach events include: (1) pre-teaching the content in the classroom prior to student participation in the event, (2) teacher active participation and encouragement of student engagement in the event, (3) involvement of pre-service teachers in these events to increase exposure and develop comfort in including Environmental Based Education outreach events in their future classrooms, and (4) incorporation of state standards into outreach curriculum development. This study highlighted important questions for future research regarding the impact of pre-teaching and post-teaching on student achievement of learning outcomes in association with these outreach events. The results of this study can be used to improve the effectiveness of STEM outreach programs in preparing students to connect science curriculum to real life applications, to engage students in science outreach events to increase interest in STEM, and to increase student achievement of State Standard derived learning outcomes.

Acknowledgments

I would like to express my deepest gratitude to Dr. Shea Tuberty, my committee chairman for his unparalleled support, guidance, and invaluable contribution throughout my graduate and undergraduate career. Thank you to Dr. Khadija Fouad, Dr. Jennifer Geib, and Lori Tyler for agreeing to serve on my committee and assisting me throughout my research. Their guidance, assistance and precious time dedicated throughout this study was invaluable and without their support, this project would not have reached its goals.

I would like to acknowledge and thank the Watauga County Schools System for allowing me to conduct research in their schools. I also wish to thank the participating Watauga County Schools eighth grade teachers for allowing me to conduct my research with their students. A special thank you to Meredith Jones with the county office for her assistance and support.

Dedication

This thesis is dedicated to my husband, for his unwavering support throughout this process. I also dedicate this thesis to my parents, whose love and endless encouragement empowered me to complete this research.

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Introduction

There is an increasing need for incorporation of STEM (Science, Technology, Engineering, Math) education into the context of real-world issues across the K-12 education continuum (National Research Council, 2011). However, despite this rising demand, there is little research into the best practices of implementing STEM education into K-12 curriculum to ultimately increase student achievement of learning outcomes and interest in STEM. Student participation in science outreach events has been shown to connect content to real life experiences, and also teach students valuable life skills such as critical thinking, problem solving and teamwork (Laursen, Liston, Thiry, & Graf, 2007; DeFelice, Adams, Branco & Pieroni, 2014). STEM outreach activities also provide students with experiences which are different than the classroom norms and can help eliminate disconnections between science curriculum and application in real life situations (Vennix, Den Brok & Taconis, 2017; Abernethy, 2017).

Environmental-based education is a practice that strives to link curriculum and student interest by using local environments to teach content while emphasizing student connectivity to their local environment (Luera & Murray, 2016; O'Connell, Oritz & Morrison, 2004). According to multiple studies, environmental-based education has been shown to increase student interest by making the content relatable and engaging (Ernst & Monroe, 2004).

This study examines EBE in the context of a local Watershed Field Day outreach event. The idea for a Watershed Field Day event first began through teachers expressing interest in having students participate in a hands-on learning activity, teaching them about the watershed concepts they were learning in the classroom. Over time, the expressed interest in this event grew, and for efficient use of time and resources, the event was scaled up to include all the middle schools in the county. The Watershed Field Day is a two-day STEM outreach event involving hands-on activities that teach students about the hydrosphere, first implemented in 2017 through a partnership with STEM-related departments at a Southern Appalachian region college, local non-profit conservation groups, the town's municipal drinking and waste water offices, the county Board of Education, and middle school science teachers. The goals of this outreach event were to educate students, using place-based education, about the watershed they live in and its environmental importance and align the focus of the individual station experiences with the state essential standards-based learning outcomes (DeFelice, Adams, Branco & Pieroni, 2014).

The five main reasons identified by schools for participation in Environmental Based Educational (EBE) outreach events include: (1) compatibility with the curriculum, (2) providing hands-on experiences for students, (3) participation of professionals and access to expert resources, (4) providing experiences with real world connectivity that teach students valuable life skills, and (5) a school climate which is supportive of environmental based education (Ernst, 2007; Ernst, 2009; Ernst, 2012; Hipkins et al., 2002). Solutions to help foster and grow these motivators in schools include opportunities for teachers to develop knowledge, attitudes and skills related to EBE through professional development opportunities (Ernst, 2007). Incorporation of these skills in pre-service teacher training could also help "cultivate an inclination to use EBE" by pre-service teachers to develop comfort in teaching in alternative settings and have a solid understanding of their local environment and training in inquiry-based instruction (the underlying principal to EBE) (Ernst, 2007). The Watershed Field Day outreach event involves pre-service teachers through the College of

Education at a Southern Appalachian region college. Pre-service teachers get the opportunity to gain valuable skills and exposure to EBE through participation in this event, hopefully, increasing their confidence in the organization and use of EBE outreach events, and incorporation of these events in their future classrooms elsewhere.

In a study completed by Ernst (2012), teachers identified the following six obstacles to EBE outreach implementation: (1) lack of funding, (2) lack of transportation, (3) state standardized testing, (4) state standards, (5) lack of teacher training in EBE, and (6) lack of planning time. Administrative support also plays a significant role; 67% of teachers at schools using no form of EBE indicated a lack of administrative support for EBE outreach events (Ernst, 2012). Participation of administrators in EBE professional development could help foster a school climate which is supportive of environmental based education.

Due to the fact that state standards and testing have become so highly emphasized in today's school environment, educating teachers and administrators in the value of EBE is of upmost importance to provide students with opportunities which connect science to real world experiences, expose them to future career opportunities, and to ultimately increase their achievement of standards-based learning outcomes (Aydeniz & Southerland, 2012; Abernethy, 2017). One of the goals of this research was to educate professionals in the value of student participation in EBE outreach events. Many people see EBE as an additional activity which could be implemented if there is extra time available, but instead teachers and administrators should be educated that EBE is not something which should be competing for instructional time. Instead, EBE is a valuable learning opportunity which incorporates state standards and enhances student learning and connection with STEM related career paths (Ernst & Monroe, 2004).

Assessment of learning outcomes is an essential part of effective program planning and implementation, and studies of science outreach events have shown that involvement in these events correlates with an increase in student content knowledge and interest in science (Felix, Hertle, Conley, Washington, & Bruns 2004). This study on the Watershed Field Day event followed a mixed methods design which was chosen because of its ability to answer difficult questions which cannot be addressed with only one paradigm (Creswell, 2014; Creswell & Creswell, 2017; Leech & Onwuegbuzie, 2009). The explanatory sequential mixed methods design model was followed in this study, consisting of quantitative data collection and analysis, followed up with qualitative data collection and analysis, and finally interpretation and analysis of emerged categories from the data (Creswell, 2014). I hypothesized that student assessment scores would increase following participation in the outreach event. I conjectured that the students who had prior knowledge of the content addressed at the outreach event would have a greater comprehension of the watershed concepts following the event and score higher on the post-assessment. I also conjectured that students would have positive influences on their perceptions of science following participation in the outreach event.

Research Objectives

The objectives of this mixed methods study were to address the following questions:

- What is the relationship between student participation in the Watershed Field Day outreach event and achievement of State Essential Standard derived learning outcomes?
- Does student participation in the Watershed Field Day Event influence their perceptions of science?

Materials and Methods

Methodology

This research is rooted in a hybrid approach of two paradigms: positivism and interpretivism, which supports the use of a mixed methods study design. The positivism paradigm is centered around the beliefs that the world is observable and consists of measurable facts (Lin, 1998). This research typically involves quantitative data and believes that there is one correct answer to a derived research question. This paradigm was chosen because the quantitative data gathered from the assessment instrument will be best interpreted using this paradigm since one of the goals of this research is to determine the relationship between student participation in this outreach event and their knowledge of watershed concepts, which is measured in the quantitative portion of the assessment instrument. However, this paradigm is not in-depth, and not focused on individuals, which is why interpretivism was also chosen. The interpretivism paradigm is centered around the belief that there is no right or wrong way to conduct research (Lin, 1998). This paradigm emphasizes the importance of context and uses emerging themes in the process of data analysis. Typically this paradigm involves qualitative data. This paradigm was chosen because it provides detailed information about the research question and believes that multiple individual's perspectives are important, allowing in-depth information to be gathered on influences to students perceptions of science.

Based on the design of this study, the results of the quantitative data are explained in more depth from the qualitative data (Onwuegbuzie & Leech, 2006). Quantitative methods were used to address research questions about student achievement of learning outcomes. Qualitative methods were used to address research questions about student perceptions of science and to further understand the results of the quantitative portion of the study. Another strength of this mixed methods study is that the study design allowed for collection of comprehensive data, providing a more in-depth picture and understanding of the impacts of student participation in the event with achievement of learning outcomes and perceptions of science (Creswell & Creswell, 2017). Grounded theory was developed using the constant comparative method, involving multiple stages of data collection (quantitative and qualitative), categorization and analysis to identify themes which emerged from the data (Creswell, 2014).

The process of triangulation was also used in this research, using quantitative data from the survey instrument, qualitative data from the interviews, and qualitative data from the survey instrument (Strauss & Corbin, 1990). The goal of using triangulation was to gather richer data, to provide validation and attempt to minimize measurement and sampling bias (Strauss & Corbin, 1990). An advantage of mixed methods studies is that the weaknesses of qualitative and quantitative data are balanced by using both data collection methods, and a greater understanding of the research problems are gained (Creswell & Creswell, 2017). Quantitative data is often weak in that it does not consider the context of the study and the views of individual participants. Qualitative data is often weak in that the findings are not generalizable, and the interpretation of the results can lead to the influence of bias from the researcher's perspective (Creswell & Creswell, 2017; Johnson & Turner, 2003).

In mixed methods research, "one of the real advantages of quantitative methods is their ability to use smaller groups of people to make inferences about larger groups" (Holton & Burnett, 1997). The response rate for the survey assessment in this study was less than half (32.67%.) Although this study has a lower participation rate and sampling bias is present, the researcher believes the sample population is a good representation of the overall population (Sandelowski, 1995). The six schools which agreed to participate in the study represent the overall socio-economic demographic of the sample population, and the small, rural schools which could largely influence the data, are included in the sample. Due to this, reliable conclusions about the overall population can be drawn, and because the process of triangulation with qualitative data from the interviews and assessment, and quantitative data from the assessment was utilized.

Table 1

Watershed Field Day Study Participants by School

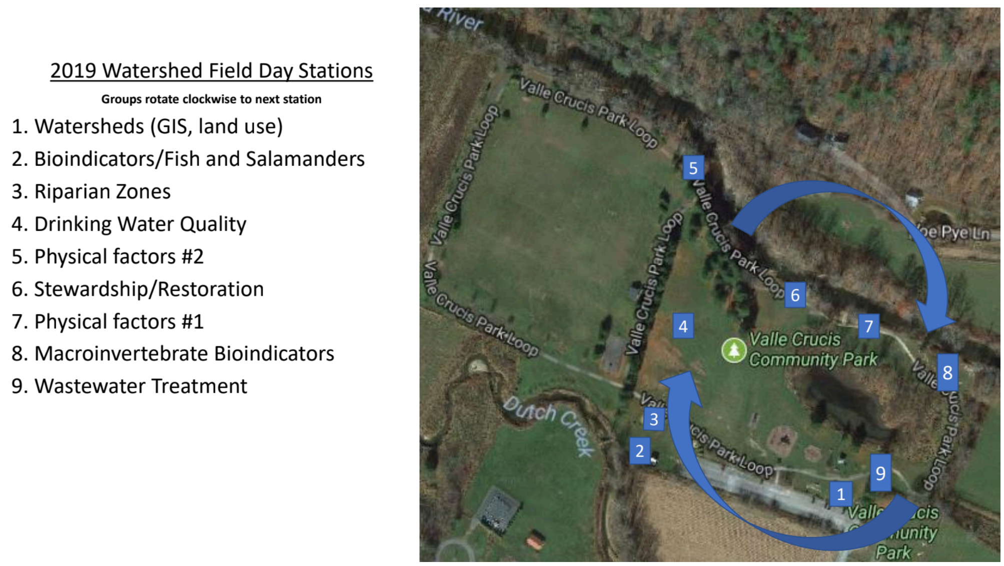
School	Number of students sampled	Total number of students	Percentage of Population Sampled
1	12	17	70.6%
2	33	109	30.3%
3	8	44	18.2%
4	31	64	48.4%
5	9	50	18%
6	5	16	31.3%
Total	98	300	32.7%

Watershed Field Day Event and Participants

The Watershed Field Day Event takes place at a local park in the County. This park was chosen because of its direct access to local streams. The event takes place during the third week in September, which was chosen because of the warm water temperatures, typically good weather, and this date allows time for teachers to pre-teach the material in the classroom. The organization of the outreach event began by recruiting the County Director of Middle Grades Science to help disseminate information about the event, aid in planning for transportation of 300 students from each of the 8 middle schools to the event, and arranging for substitute teachers and chaperones for the event. Teachers provided the number of students in their classes to help with planning for groups, and more than 40 volunteers were recruited to lead the nine activity stations over the 2-day event. Station focused exercises were designed to engage students in hands-on activities and a data worksheet was developed, consisting of take away lessons from each station. At each station students completed this data analysis and watershed concepts worksheet which required them to answer questions about the topics being taught, and spend time reflecting on the information presented (Appendix C). The study group of this outreach event were 300, 8^{th} grade students in the Southern Appalachian region, from eight different public schools (K-8); of the total number of participants in the event, 98 students from six different schools agreed to participate in the research study. A breakdown of the participant numbers by school can be seen in Table 1. On each day of the outreach event, four schools participated and students were separated into groups according to their science class, with no more than 25 students per group (further split into two groups each (10-12/group) to allow for dual activities at some of the stations). Throughout the event, student groups cycled clockwise through nine different stations (see Figure 1), spending 25 minutes at each (an airhorn was used to indicate time to advance to the next station), where different watershed concepts were taught. The station locations were specifically chosen based upon the content being delivered, with five of the stations allowing students to directly access the streams. The approximately 40 volunteer presenters for the event were from a variety of organizations, including: a Southern Appalachian region College, State Wildlife Resource Commission, local town departments, and several other nonprofit environmental or conservation organizations and were comprised of faculty and field experts, undergraduate and graduate students, and pre-service education majors. Prior to the event, volunteers were provided with a list of learning outcomes, derived from the State Science Essential Standards to be addressed at each of the stations. By providing this information, the researcher aimed to create a standardization of content, so that each student received a similar educational experience.

Figure 1

Activity Stations Map Overlaid on Satellite Image of Site Location



For the purposes of this event, hands-on activities are defined as learning opportunities in which students are collecting data and measurements such as collecting and macroinvertebrates. “Hands-on, minds-on” activities are defined as learning opportunities which require students to think critically to use the information presented to them, and analyze and interpret it into a larger context; for example, students would use their knowledge of water chemistry to analyze their collected measurements and determine the quality of the stream. All stations at the event consisted of either hands-on, or “hands-on, minds-on” environmental based learning activities. The nine stations students cycled through include: macroinvertebrates as bioindicators, vertebrates as bioindicators, riparian zones and the water cycle, wastewater treatment, stewardship and restoration, watershed concepts, and two stations of physical factors (Figure 1). Throughout these stations, students participated in a variety of activities, with four of the eight activities allowing students to get in the streams and sample various parameters to determine water quality. At each of the stations, students completed a data analysis worksheet which provided them with an opportunity to reflect on the information being taught, and help guide them through the learning outcomes for each station (Appendix C). Station 1 investigated how scientists use GIS to monitor land use and its effects on water quality, along with how the boundaries of a watershed are determined and how healthy watersheds are maintained. Station 2 looked at darters, trout and salamanders and their role in freshwater ecosystems. Station 3 discussed the importance of riparian zones and the ecological benefits they provide, along with an overview of the water cycle and its impacts on stream ecology. Station 4 investigated how water quality is monitored in the United States, and the importance of safe drinking water. Station 5 showed students how scientists measure different water chemistry parameters, including: pH, temperature, dissolved oxygen, flow and conductivity, and what these parameters can tell us about water quality. Station 6's objectives included teaching students how landowners can protect water quality (stewardship) and what measures can be taken to improve degraded streams. Station 7 examined erosion, sedimentation, turbidity and nutrients and how these impact aquatic ecosystems. Station 8 investigated aquatic macroinvertebrate bioindicators (e.g. insects, snails, worms and crayfish) and their role in aquatic ecosystems. Lastly, station 9 guided students through the process of wastewater treatment and how water quality is ensured throughout this process. See Appendix D for in-depth information about the activities at each station.

Measurement Tools and Data Collection

One of the goals of this research was to determine if participation in this hands-on outreach event affected student achievement of standards-based learning outcomes. To assess this, students participated in preliminary and post testing, which measured the impact of the outreach event on their achievement of the learning outcomes derived from the State 8^{th} Grade Science Essential Standards (Table 2). The assessments were piloted one year prior to their implementation for this research with a group of 40, 8^{th} grade students from one of the schools participating in this research study. To improve the reliability and validity of the questions on the assessment, appropriate adjustments to the assessment instrument were made incorporating the lessons learned from the pilot test, regarding the clarification of question wording and question expectations (Brink, 1993). The teacher monitored assessment was delivered electronically to each student who participated in the study within the week before and within the week following the outreach event. The structure of the assessment consisted of 20 total questions, both quantitative (15 questions) and qualitative (5 questions) in nature. The questions were designed to investigate student knowledge of the watershed concepts addressed at the event, while also capturing any changes in student's perceptions of science. The assessment questions consisted of multiple choice, fill in the blank and short answer responses, and all of the quantitative questions were derived from the learning outcomes, based upon the State 8^{th} Grade Standard Course of Study. The full assessment is available in Appendix A. Teachers were also asked to provide information about whether or not the content addressed at the outreach event was pre-taught in the classroom; Schools 1, 3, 4 and 5 all pre-taught the material, while 2 and 6 did not pre-teach (Table 4).

Table 2

*State Science Essential Standards Derived Learning Outcomes and Associated Question on Assessment. * Decrease in average percent correct from pre to post-assessment*

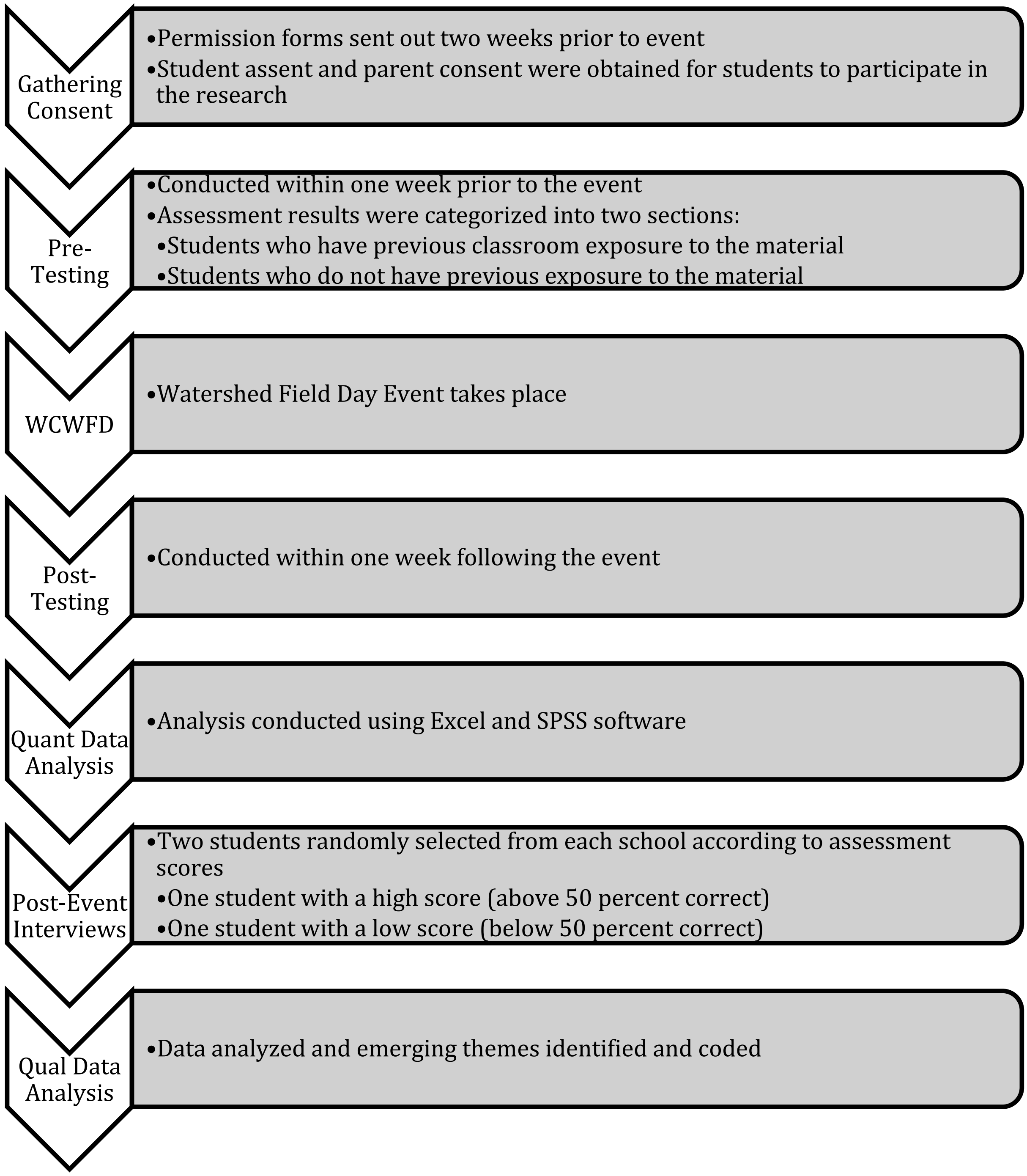
NC Essential Standard	Derived Learning Outcomes	Related Question(s) on Assessment	Pre-Assessment % Correct	Post-Assessment % Correct
8.E.1.1- Explain the Structure of the hydrosphere including: water distribution on earth, and local river basin and water availability	Students can correctly list the distribution of water on earth Students can accurately list and define the parts of the water cycle, including: condensation, evaporation, precipitation, runoff, and infiltration Students can accurately list the factors which determine the area of a watershed	1(a-g)	1a. 95.9% 1b. 74.7% 1c. 82.8% 1d. 91.9% * 1e. 91.9% 1f. 49.4% 1g. 63.6%	1a. 96.9% 1b. 78.7% 1c. 83.8% 1d. 88.8% * 1e. 93.9% 1f. 61.6% 1g. 71.7%
		2	81.8% *	74.7% *
		3	63.6%	70%
		13	39.3%	56.5%
8.E.1.3- Predict the safety and potability of water supplies in North Carolina based on physical and biological factors	Students can correctly define what a bioindicator is Students can list the abiotic and biotic factors which affect fish survival Students can correctly interpret a pH scale Students can accurately describe how temperature impacts an aquatic ecosystem Students can correctly define what dissolved oxygen (DO) is, and provide example sources of DO in an aquatic system Students can define what nitrates and phosphates are, and list potential sources of each. Students can correctly define what turbidity is, and potential source inputs to an aquatic system.	4	38.3%	67.7%
		5	28.3%	47.5%
		6	26.3%	42.4%
		7	68.6%	85.8%
		8	41.4%	57.5%
		9	33.3%	49.4%
		11	35.3%	45.4%
		14	44.4%	67.6%

NC Essential Standard	Derived Learning Outcomes	Related Question(s) on Assessment	Pre-Assessment % Correct	Post-Assessment % Correct
8.E.1.4- Conclude that the good health of humans requires: monitoring of the hydrosphere, water quality standards, methods of water treatment, maintaining safe water quality, stewardship	Students can accurately describe why water quality is important Students can describe how water quality is monitored in the U.S.	10	91.9%	98.9%
		12	26.2% *	21.2% *

In addition to the assessment instrument, interviews were completed with twelve students, within two weeks following the outreach event. From each of the six participating schools, two students were randomly selected using a random number generator according to their assessment scores. One student with a high score (above 50 percent) and one student with a low score (below 50 percent) were selected. The interviews were semi-structured and consisted of six questions with an approximate 20-minute time frame. Questions were adapted and modified from the 10^{th} grade student interview instrument used in the 1993 study by Ebenezer and Zoller. Each interview began with the researcher asking the following question: "Did you enjoy participating in the Watershed Field Day Event? What parts did you like the most? The least?". Other questions such as "Do you like science? Why or why not?" and "Do you think science is important? Why or why not?" followed. The full interview questionnaire is available in Appendix B. The students expressed their answers to the interview questions openly, and without any noticeable hesitation. Answers to the interview questions were audio recorded for later transcription and then coded into themes for further analysis. A visual model for the study design can be seen in Figure 2.

Figure 2

Study Design Model and Workflow for the 8th Grade Watershed Field Day Assessment of Learning Outcomes



Data analysis

Throughout the data analysis process Grounded Theory's constant comparative method was used (Creswell, 2014). Data analysis started once students had taken the pre-assessment. Before the outreach event took place, data from the pre-assessment were analyzed to identify re-occurring themes. The next step in the study design was the implementation of the outreach event, during which the researcher made observations in field notes to gain a greater understanding of the participants in the study and the impact of the event, comparing these to the themes identified from the pre-assessment. Next, the post-assessment data were analyzed and the results were compared to the data from the pre-assessment and the observations collected from the event. Prior to conducting interviews with the randomly selected students, their pre/post assessment data were analyzed, noting themes present in the data and areas where clarification was needed, which the researcher would attempt to elaborate on in the interviews. Interviews were then conducted with selected students to learn more about the impact of the event on their understanding of watershed concepts and perceptions of science. Once all data from the study had been collected, the themes noted throughout the collection process were compared, emerged themes were identified, and research questions were addressed. Throughout each step of the study, data were continually sorted through and comparisons were made between each data collection method in order to identify emerged themes.

The quantitative data from the pre/post assessment were analyzed using the statistical software IBM SPSS version 26.0. First, the data were analyzed for normality by looking at the distributions and completing a Shapiro-Wilk goodness-of-fit test. A simple analysis of the mean pre/post-assessment scores and standard error for each school was completed. Next, a paired samples *t*-test was completed to analyze the pre-assessment and post-assessment scores for all schools to determine statistical significance. Then, a one-way ANOVA was completed to compare the pre-assessment and post-assessment scores of each school to one another, followed by a Post-hoc Tukey test to determine differences between schools. Lastly, a one-way ANOVA was completed to determine if the improvement from pre-assessment to post-assessment for each school was statistically significant.

Results

Objective #1: What is the relationship between student participation in the Watershed Field Day outreach event and achievement of State Essential Standard derived learning outcomes?

The results of the normality tests for pre- and post-assessment scores revealed the data were normally distributed. The average pre-assessment score was 56%, the average post-assessment score was 66% (Table 3). School 2 had the lowest average pre-assessment score (42.58%) and the lowest post-assessment score (55.39%). Five of the six schools had an increase in mean assessment score from pre- to post-assessment (Table 3). School 6 showed no growth from pre- to post assessment (58.9% average) and the highest standard error (SE = 7.36). Schools 2 and 6 did not teach the material prior to the outreach event taking place (Table 4). School 2 scores saw the largest growth from pre- to post-assessment. Schools 1, 3 and 6 had the lowest growth from pre- to post-assessment, however, Schools 1 and 3 were in the top three highest pre-assessment scores, with 6+ points above the average pre-assessment score.

The paired samples *t*-test data revealed there was a statistically significant difference between the pre-assessment and post-assessment scores ($p < 0.0001$), meaning that the average assessment score for each school was different from the start. A strong linear correlation was present between the pre-assessment and post-assessment scores, suggesting that pre-assessment score predicts post-assessment score (Figure 3). A significant difference in pre-assessment scores between schools ($p < 0.0001$) and in post-assessment scores between schools ($p = 0.0002$) was determined (Figure 4, 5). The Post-hoc Tukey test revealed a difference in pre-assessment scores between Schools 1 and 2 ($p = 0.002$), Schools 2 and 3 ($p = 0.002$), Schools 2 and 4 ($p < 0.0001$). A significant difference in the post-assessment scores was present between Schools 2 and 4 ($p = 0.000039$). School 3 had the greatest variance of pre-assessment scores (Figure 4). Schools 4 and 2 had the greatest variance of post-assessment scores, while Schools 5 and 6 had the least variance (Figure 5). Student improvement on the assessment between schools was not statistically significant ($p = 0.1215$), meaning that student improvement on the test did not differ by school.

Table 3

Pre/Post Assessment Means, Standard Error and Score Percent Difference by School

School	**Pre-test Mean (%)**	**Std. Error**	**Post-test Mean (%)**	**SE**	**Δ Score**
1	62.48	4.34	67.13	4.75	4.65
2	42.58	2.62	55.39	2.86	12.81
3	65.96	5.31	71.51	5.82	5.55
4	66.30	2.69	75.97	2.96	9.67
5	56.78	5.01	69.13	5.48	12.35
6	58.90	6.72	58.90	7.36	0
Mean	56	4.45	66	4.87	7.51

Table 4

Schools that Pre-Taught the Material Prior to the Outreach Event and Those Who Did Not

Schools which began teaching the material prior to the event	Schools which did not teach the material prior to the event
1	2
3	6
4	
5	

Figure 3

Regression Analysis of Pre-Assessment vs. Post-Assessment Scores. Dots Represent Student Scores on the Assessment, Alike Scores are Represented by one Dot.

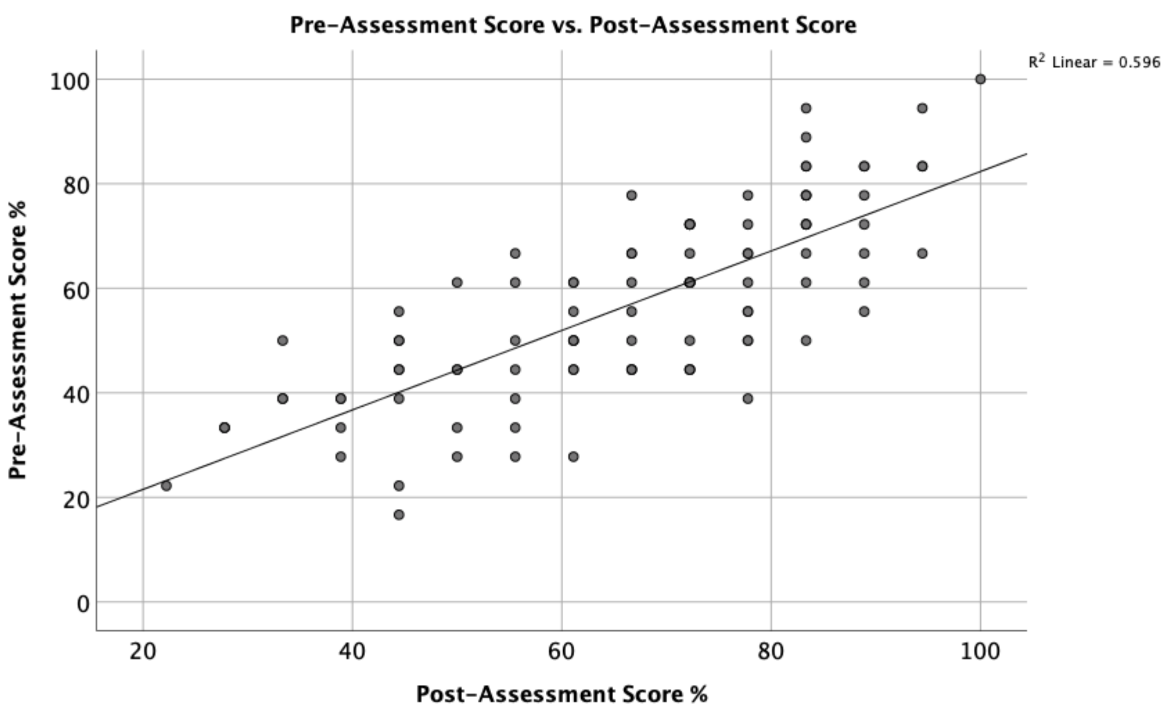


Figure 4

Pre-Assessment Comparison of Mean Score by School

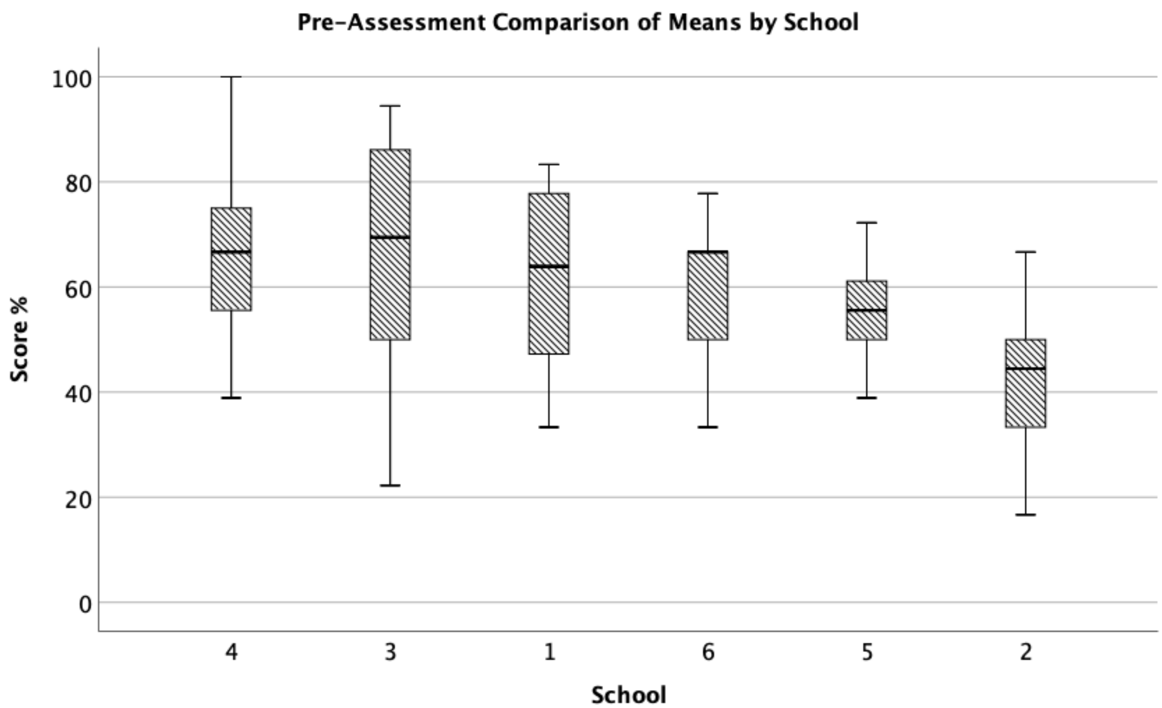
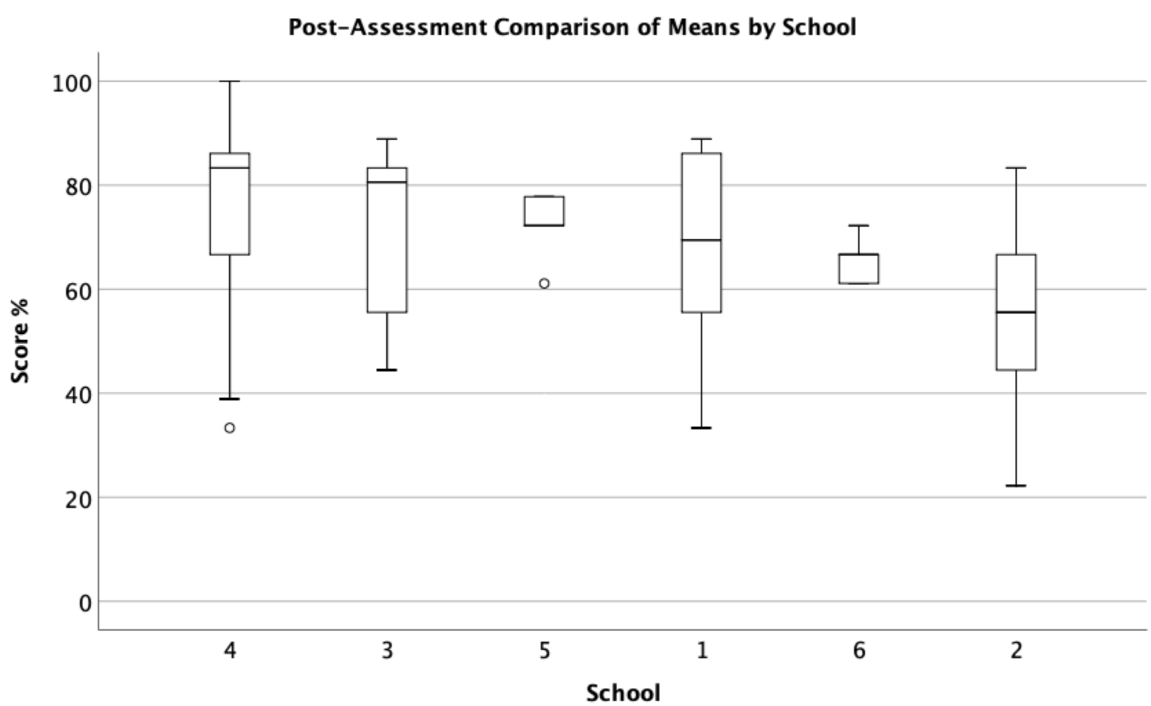


Figure 5

Post-Assessment Comparison of Mean Score by School



Objective #2: Does student participation in The Watershed Field Day Event influence their perceptions of science?

A visual model of the emerged themes can be seen in Table 5. Students were identified in this study using their school's assigned number (1-6) and their random numerical identifier assigned by their teacher. During the student interviews, the majority (10 of 12) students stated they enjoyed participating in the event because of the hands-on activities, but the minority (2 of 12) stated they did not enjoy participating in the event (students 2-1; 2-21). These two students were also part of the minor theme (3 of 12 students) which stated that they were not more interested in science after participating in the event because they thought the event was boring because they "didn't like being talked to or lecture style teaching". The other student (6-1630) in this theme, who attended a different school, stated their reason was "the event was long and I don't like science so I got tired of it".

Table 5

Qualitative Data Major (white) and Minor (grey) Emerged Themes from Student Interviews

Theme	Selected Quote from Interviews	Number of students with responses related to theme (12 total students)	# of schools represented in responses (6 total schools)
Enjoyed event because of the hands-on activities	"I liked the event because we got to do hands-on things like playing in the water which made it easier to learn and remember."	10	6 (All Schools)
Prefer hands-on teaching methods in science class	"I like doing hands-on things in science class because it makes me feel like I am actually doing science and I understand it better."	11	6 (All Schools)

Theme	Selected Quote from Interviews	Number of students with responses related to theme (12 total students)	# of schools represented in responses (6 total schools)
Believe that science is important	"Science is important because it helps us understand how things on Earth work and gives us information about how to take care of the things that help us."	12	6 (All Schools)
Student is more interested in science after participating in the event	"During the event I got to see things that I didn't even know existed like the macroinvertebrates so this made me think more about science and the cool stuff you get to do."	9	5 (Schools 1, 3, 4, 5, 6)
Like science and science class	"I like science class because we are always doing something and moving around and it makes me feel accomplished after I do these things."	9	5 (Schools 1, 3, 4, 5, 6)
Did not enjoy event, thought it was boring and not interesting	"I didn't really like the event because it was long, we had to listen a lot and I don't like science so I got tired of it."	2	2 (School 2, 6)
Not more interested in science after participating in the event;	"I am not more interested in science after the event because science is complicated and hard to understand."	3	2 (School 2, 6)
Never liked science, hard to understand, boring	"Science is the only class I don't enjoy because it is hard to understand. I don't want to learn it and I always do bad on tests."	3	2 (School 2, 6)
Does not like science class, boring	"I don't like science class, all we do is take notes, sit and listen."	3	2 (Schools 2, 6)

Further analysis of the data from students 2-1, 2-21 and 6-1630 revealed that their responses in the interviews included that they did not like science, nor did they like science class. These three students were from two different schools. Interestingly, these were the two schools which did not pre-teach the material, and these two schools also had the lowest average post-test scores out of all schools. School 6 saw no change in average from pre-test to post-test, and School 2 did see a 13.5% increase in average score from pre- to post test, but this school's post-test mean was the lowest average score out of all the participating schools.

Further analysis of these schools revealed that student 6-1630 had a pre-test score of 52.9%, and a post-test score of 64.7%, meaning a growth of 11.8%. Student 2-1 had a pre-test score of 52.9%, and a post-test score of 64.7%, meaning a growth of 11.8%. This student stated that they enjoyed the event and the hands-on activities, but their responses to all other questions in the interview had negative themes, stating that they were not more interested in science after the event and they did not enjoy science, nor science class. Student 2-21 had pre-test score of 41.2%, and a post-test score of 82.4%, meaning a growth of 41.2. Although each of these student's responses aligned with negative themes from the interview data, the quantitative data revealed that there was a positive impact of the event on their achievement of learning outcomes based on their pre/post assessment scores alone.

On the pre/post assessment, three Likert Scale questions were asked to evaluate student's perceptions of science. Histograms for each of the three questions and the percentages of each student response are below, with error bars that represent the 95% confidence interval. Student responses to the statement "I believe that science impacts my daily life" resulted in a 7.1% increase in the "Very Much" selection from pre-assessment to post-assessment (Figure 6). On the post-assessment, 87.9% of students stated that they think science has some impact on their daily lives. Student responses to the question "How interested in science are you?" saw a 5.4% decrease in the "Very Interested" selection, a 1.6% increase in the "Somewhat Interested" selection, a 1.5% increase in the "Neutral" selection, and a 3.9% increase in the “Not Really Interested” selection from pre-assessment to post-assessment (Figure 7). On the post assessment, 65.7% of students stated that they have some interest in science. For the last question on the assessment, student responses to the statement “I think about water quality and my impact on the environment on a daily basis” saw a 3.6% decrease in the “Almost Always” selection, and a 6.1% increase in the “Sometimes” selection (Figure 8). On the post-assessment, 66.7% of students stated that they often think about water quality and their impact on the environment.

Figure 6

Pre- and Post-Assessment Student Selected Response to the Impact of Science

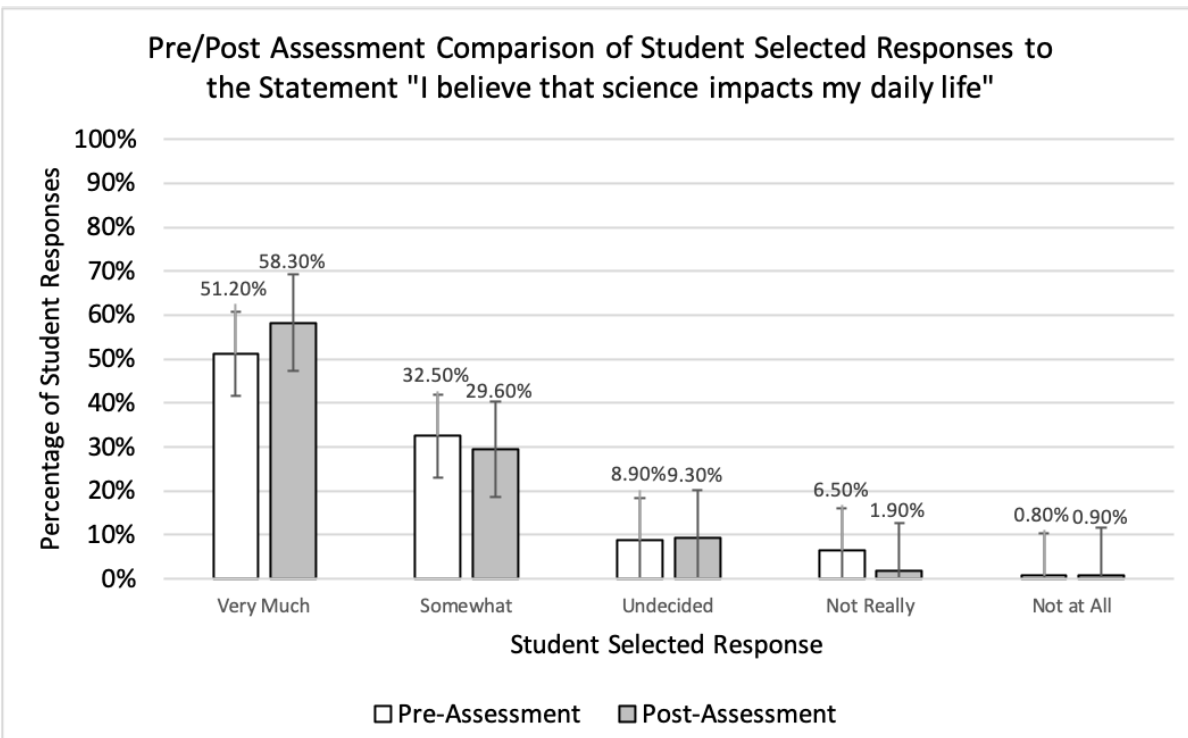


Figure 7

Pre- and Post-Assessment Student Selected Response to their Interest in Science

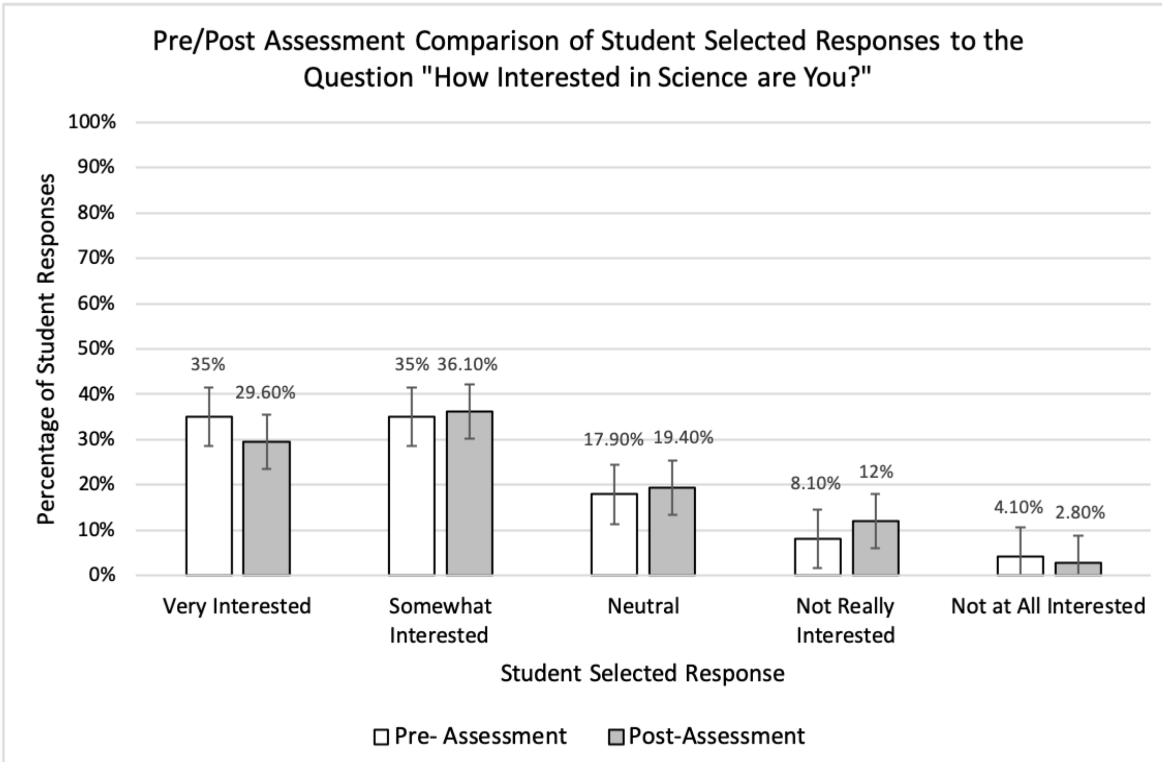
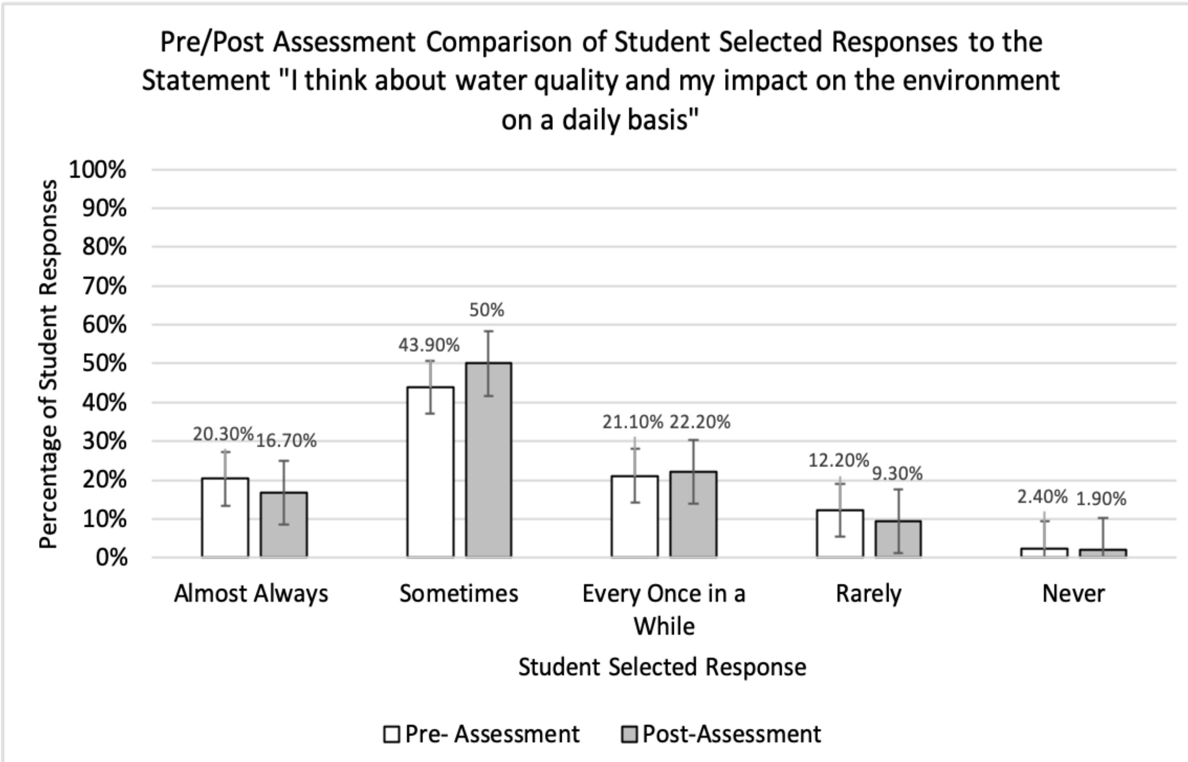


Figure 8

Pre- and Post-Assessment Student Selected Response to their Impact on the Environment



Discussion

The Watershed Field Day is an Environmental Based Education outreach event which provides students with hands-on, real-world educational experiences which incorporate State Essential Standards, increases student achievement of learning outcomes and supports modest, positive perceptions of science.

Objective #1: What is the relationship between student participation in the Watershed Field Day outreach event and achievement of State Essential Standard derived learning outcomes?

It is likely that one of the factors contributing to the increase in average assessment score is the assessment questions and information taught at each station being closely aligned by providing presenters with the learning outcomes for each station. Additionally, the assessment questions were created directly from the learning outcomes derived from the State Standard Course of Study for 8th Grade Science. Prior to the event, each of the volunteer presenters were provided with a copy of the learning outcomes expected of students for their particular station they were leading. This practice helped closely align the content delivered at the stations with the material assessed on the pre- and post-test.

On average, pre-post-assessment mean scores improved by an average of 10% (a full letter grade) across the six schools included in the analysis. However, the growth/decline from pre- to post-assessment for each individual school was examined and indicated that one participating school (School 6) did not see any growth in average assessment score from pre- to post-assessment. It is hypothesized that this is related to two observed factors: a lack of teacher active participation and encouragement during the event, and no pre-teaching of the material prior to the event. As noted in the field observations, the students from this school were not highly focused during the outreach event, and lack of teacher encouragement of student attention may have contributed to this lack of growth. There was a significant difference in pre-assessment scores of School 2 when compared to Schools 1, 3 and 4. A significant difference in the post-assessment scores was also present between Schools 2 and 4. School 2 had the lowest average post-assessment score, but the greatest difference in pre- and post-assessment score. The teachers who pre-taught the material prior to students participating in the event had overall higher mean scores on the pre and post-assessment. There is a possible link between student achievement of learning outcomes and pre-teaching of the material which can be seen in the quantitative data of assessment scores, and qualitative data of interviews. It is possible that the students whose teachers pre-taught the material were able to make deeper connections with the material they were learning at the outreach event, which can be observed in the following quote from a student interview: "I felt like what we learned in class was proven and strengthened during watershed day. For example, we learned about pH in class, but during watershed day, we used tools that actually showed pH."

The data gathered in the study supports the hypothesis that student assessment scores would increase following participation in the outreach event. The data also supports the conjecture that the students who had prior knowledge of the content addressed at the outreach event would have a greater comprehension of the watershed concepts following the event and score higher on the post-assessment. However, because detailed data was not collected on the amount of post-teaching in the classroom which took place before students completed the post-assessment, it is possible this could have an influence on student achievement of learning outcomes and comprehension of watershed concepts as well.

Upon analysis of the pre- and post-assessment data, there were three questions on the assessment which lowered in the total percentage correct from pre- to post-scores (Table 2). Question 1d, Learning Outcome: Students can accurately list and define the parts of the water cycle, including condensation, evaporation, precipitation, runoff, and infiltration. Pre-assessment percentage correct 91.9%, post-assessment percentage correct 88.8%. Question 2, Learning Outcome: Students can correctly list the distribution of water on earth. Pre-assessment percentage correct 81.8%, post-assessment percentage correct 74.7%. Both of these learning outcomes were addressed at station three (Riparian Zones). Due to the nature of the content delivery at this station, it had a more direct instruction style in that the information was presented to the students, and they wrote it down on their data sheets, while students participated in short demonstrations and activities. Students did not participate in "hands-on, minds-on" learning at this station. Question 12, Learning Outcome: Students can describe how water quality is monitored in the United States. Pre-assessment percentage correct 26.2%, post-assessment percentage correct 21.2%. This learning outcome was addressed at Station 4 (Safe Drinking Water Quality). Station 4 was also a station which involved more direct instruction due to the nature of the content, which could be one of the reasons why students did poorly on this learning outcome. The data gathered from these three questions support the conclusion that students have greater achievements in learning outcomes when involved in hands-on and "hands-on, minds-on" activities.

Objective #2: Does student participation in the Watershed Field Day Event influence their perceptions of science?

Of the twelve total students interviewed, ten (83%) said that they enjoyed the event, and nine (75%) said that they were more interested in science after participating in the outreach event. One important quote noted from the interviews highlights student opinions on their participation in the event: "Well I didn't really know much about our watershed other than the lessons we had gone over in class but now I know the actual scientific reasons and why it matters so much to our environment."

One student stated in her interview that she has now decided she wants to pursue a career in science because she enjoyed the event so much. Two other students also stated that after participating in the event, they now understand how they can have a positive impact on the environment. In the assessment, the 7.1% increase in student selection of the response "Very Much" to the statement "I believe that science impacts my daily life" suggests that this event is effectively using environmental based education to teach students about the science present in their everyday lives, although no statistically significant difference was present.

Although there was a 5.4% decrease in the percent of students who chose the response “Very Interested” to the question “How interested in science are you?”, overall there was not a statistically significant change in responses to this question from pre- to post-assessment. Although these were not the desired results for this question, more than half (65.7%) of students stated that they have some interest in science, which is positive. For the last perceptions question on the assessment, there was a 6.1% increase in the number of students who chose the response “Sometimes” to the statement “I think about water quality and my impact on the environment on a daily basis”, but no significant change was present in the data from pre-assessment to post-assessment for any of the Likert Scale questions. Although there was no statistically significant difference present, over half of the students surveyed (66.7%) stated that they often think about water quality and their impact on the environment on a daily basis. This data suggests that what educators and community members are currently doing with students in this region is having a positive impact on their perceptions of science. The data gathered in this study supports the conjecture that students would have positive influences on their perceptions of science following participation in the outreach event. However, the results from this portion of the study opens an area for future research to determine the long-term impact of this event on students perceptions of science. Studies have found that students perceptions of science become less positive as they move through school (Speering & Rennie, 1996). Therefore, determining the long-term impact of their experience at this event could reveal interesting data on implications for career choices and adult perceptions of science (Speering & Rennie, 1996).

Participation in the Watershed Field Day Event has a modest positive impact on student’s perceptions of science, and also increases student achievement of State Essential

Standard-based learning outcomes for 8th grade science. This event allows students to participate in a hands-on learning event, and 100% of students interviewed stated that this was their preferred method of teaching in science class. In this event, students also gain exposure to technology which is not available in most classrooms, such as water chemistry probes and electrofishers, as well as contact with community professionals in the field.

The results of this study support those of similar studies in that Environmental Based Education outreach events provide students with hands-on, and “hands-on, minds-on” activities which when linked to State Essential Standards, can help increase student achievement of standards-based learning outcomes, and influence positive perceptions of science (Felix et al., 2004). To increase the incorporation of these events into K-12 classrooms, organizers must inform educational professionals about the benefits of these studies, such as increased achievement of learning outcomes as shown in this study, along with developing critical thinking, problem solving and team work skills as highlighted in similar studies (Laursen et al., 2007). For schools to be interested in participating in these outreach events, event coordinators must work towards meeting the main reasons schools choose to participate in EBE as described by Ernst (2007, 2009, 2012) and Hipkins et al. (2002). In this study four of the five reasons were directly met. The fifth reason of a school environment which is supportive of EBE was mostly met, but the data gathered from this study was evidence used to support and develop this last factor. The six strongest obstacles for schools choosing to participate in these outreach events were also strongly considered in this study, to attempt in minimizing the impacts, or addressing these obstacles (Ernst, 2012). The results of this study can be used to support the idea that these outreach events utilize and incorporate state standards and are a valuable learning experience which helps prepare students for state standardized testing. Administrative support is also a major obstacle to the implementation of these outreach events, and following this study, administrators were provided with the data to show that student participation in this event correlated with an increase in student achievement of learning outcomes in hopes of increasing support of this event.

Triangulation was used in this study to attempt to minimize bias, however, there is still bias present and one of the weaknesses of this study includes the presence of sampling bias (Onwuegbuzie & Collins, 2007). Although the study design consisted of sampling the entire population, of the 300 total participants in the event, only 98 were included in this research study because of teacher and student unwillingness to participate. However, the sample population is a good socio-economic representation of the overall population demographics for this Southern Appalachian region target population.

Conclusion/Future Directions

This study represents an initial attempt at understanding the relationship between student participation in STEM outreach events, and achievement of standards-based learning outcomes and influences on perceptions of science. The results of this study have illuminated important questions to be addressed in future research. From the data gathered in this study, it can be hypothesized that students receive the greatest positive impact from this outreach event if teachers pre-teach the material prior to the event. The average pre- and post-assessment scores were higher from students who were taught the material in the classroom prior to the event, than those teachers who taught the material after the event. Students who were taught the material prior to the event showed signs of a greater impact from the event in both their average assessment scores, as well as their responses to interview questions. For example, the following quote was taken from an interviewed student whose teacher had pre-taught the material prior to the event: “Many topics that we had discussed in class were brought up and elaborated on. I learned many things and believe that this field trip has better helped me to understand how people affect their local ecosystems and how you can encourage water conservation, and help keep the quality of the streams and rivers in our county clean.” This area of the research rises the potential for further studies on this topic to gain a greater understanding of the relationship between pre-teaching, and student achievement of learning outcomes. Advice for future studies includes gathering more information on the duration of pre-teaching prior to the event, along with the specific content being pre-taught. It is hypothesized that post-event teaching which occurs prior to students taking the post-test, also plays a role in this relationship, and more data on this is needed to further understand how this also influences student achievement of learning outcomes.

Another area for future research includes examining whether the outcomes of this study would be different if the volunteer presenters for the Watershed Field Day event had received more training on best practices for running the stations, instead of just receiving the list of learning outcomes for their station.

Other best practices I would suggest for future outreach events are teacher encouragement and involvement with students during the event. The teachers who were actively participating, questioning and interacting with students at the stations during the event helped keep these students engaged and focused on the material, and therefore these students had greater positive gains in knowledge and understanding of the material addressed at the outreach event. Comparing the quantitative survey data to observational data collected during the outreach event, it appears there is a relationship between increased student scores on the post-assessment, and teacher involvement during the event. The teachers who were encouraging student participation and encouraging students to think about what they were learning by asking them questions while they were at the stations, saw larger gains in student assessment scores.

To continue improving the success and impact of the Watershed Field Day Event, modifications will be made to the stations which were linked to decreased student achievement of learning outcomes, to a more “hands-on, minds-on” instructional format, in attempt to improve student gains at these stations. The data gathered from this study supports the idea that incorporation of environmental based educational practices have significant benefits to student learning and perceptions of science. It is the hope of the researcher that schools will use this data to inform their instructional practices to have the greatest positive impact on student achievement of learning outcomes and perceptions of science.

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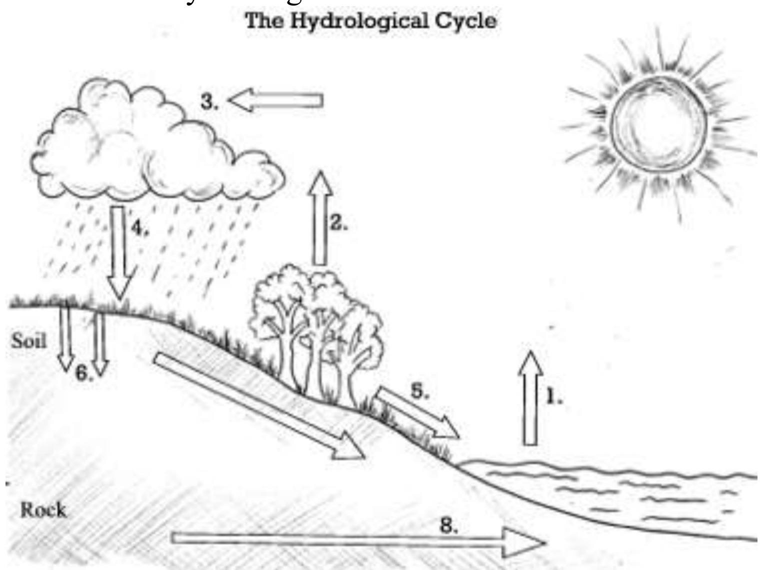
Appendix A: Survey Instrument

Please answer the following questions as best you can. This activity will not be graded. This will be used to see what you know about these topics. Don't worry if you don't know some of the answers. Just write down what you know and give it your best guess.

1. Match each part of the water cycle listed below with the corresponding number listed on the water cycle diagram.



    a) Precipitation
    b) Evaporation
    c) Condensation
    d) Infiltration
    e) Runoff
    f) Groundwater
    g) Transpiration

2. What percent of the Earth's surface is water?
    a) 50%
    b) 65%
    c) 71%
    d) 89%
    e) None of the above

3. What percent of the water on Earth is freshwater?
    a) 35%
    b) 50%
    c) 3%
    d) 11%
    e) None of the above

4. Which abiotic factors affect a fish's survival?
    a) Predation, Competition, Disease
    b) Water temperature, Oxygen in the water
    c) Predation, Oxygen, Disease
    d) Food Availability, Competition, pH
    e) All of the above are abiotic factors

5. Which biotic factors affect a fish's survival?
    a) Predation, Water temperature, Oxygen in the water
    b) Water temperature, Oxygen in the water, Competition
    c) Competition, Predation, Food Availability
    d) Food Availability, Disease, Water temperature
    e) All of the above all biotic factors

6. Short Answer. What is a bioindicator?

7. Which of the following is considered a neutral pH?
    a) 5
    b) 14
    c) 1
    d) 7
    e) 2

8. What is a potential source of nitrates in aquatic ecosystems?
    a) Roads
    b) Fertilizers
    c) Rainfall
    d) None of the above
    e) All of the above

9. What is a potential source of phosphates in aquatic ecosystems?
    a) Animal waste
    b) Sewage leak
    c) Laundry water pumped into a stream
    d) None of the above
    e) All of the above

10. Is water quality important to humans? Explain why or why not.
11. What is turbidity?
    a) How fast water moves through a stream
    b) The amount of sediment suspended in the water column
    c) How far sunlight passes through water
    d) The amount of pollution in a water body
    e) The amount of salt in a water body

12. At what government level is water quality monitored in the United States?
    a) State
    b) Federal
    c) Local
    d) None of the above
    e) All of the above

13. How is the area of a watershed determined?
    a) By local agencies
    b) By topographic divides
    c) By weather
    d) By federal agencies
    e) By the animals living in that area

14. Short Answer. A nearby town is proposing the building of a new riverfront apartment complex along a river, in a currently undisturbed forested area. Residents of the nearby neighborhood are protesting the construction because they believe it will be bad for the local water quality. How could the new complex impact water quality in terms of temperature, dissolved oxygen and riparian vegetation? *

15. Short Answer. How was your understanding of watershed concepts affected by attending the Watershed Field Day? Give specific examples of how your understanding was affected. (*Only assessed on the Post-Test)

16. Choose the response which best reflects your opinion. I believe that science impacts my daily life.
    - ☐ Very Much
    - ☐ Somewhat
    - ☐ Undecided
    - ☐ Not Really
    - ☐ Not at All

17. For this question please select very much.
    - ☐ Very Much
    - ☐ Somewhat
    - ☐ Undecided
    - ☐ Not Really
    - ☐ Not at All

18. Choose the response which best reflects your opinion. I think about water quality and my impact on the environment on a daily basis.
    - ☐ Almost Always
    - ☐ Sometimes
    - ☐ Every Once in a While
    - ☐ Rarely
    - ☐ Never

19. Choose the response which best reflects your opinion. By participating in this event, I learned new information about the local ecosystem.
    - ☐ Very Much
    - ☐ Somewhat
    - ☐ Undecided
    - ☐ Not Really
    - ☐ Not at All
20. Choose the response which best reflects your opinion. How interested in science are you?
    - ☐ Very Interested
    - ☐ Somewhat
    - ☐ Neutral
    - ☐ Not Really
    - ☐ Not at All

Appendix B: Interview Questionnaire

Assessment of Student Learning Outcomes from Involvement in Hands on STEM Outreach Events

The interviews conducted in this study will be semi-structured and consist of approximately 6 questions with an approximate 20-minute time frame. Questions were adapted and modified from the interview instrument used in the 1993 study by Ebenezer and Zoller.

1. Did you enjoy participating in the Watershed Field Day Event? What parts did you like the most? The least?

2. After participating in the Watershed Field Day event, are you more interested in science? What particular parts of the event made you more or less interested in this topic?

3. Do you like science? Why or why not?

4. Do you think science is important? Why or why not?

5. Do you enjoy attending science class?

6. In your science classes, what methods of teaching do you prefer?

Appendix C: Watershed Field Day Event Student Handout and Notes

Station 1: Watershed Concepts
Define: What is a river basin or watershed?

What factors determine the area of a watershed?

How does the land use/land cover of your watershed effect its health?

Which local watershed do you live in?

Where does this water go? (The larger watershed your river is part of)

Station 2: Vertebrate Bioindicators – darters, trout, salamanders
What is a vertebrate bioindicator?

What species of fish were found in Dutch Creek?

What types of biotic and abiotic factors can affect fish survival?

If multiple size classes (ages) of fish are found what does this tell you about the water quality over time?

How old are stream fishes?

Station 3: Riparian Zones & The Water Cycle
What is a riparian zone?

List the benefits of riparian zones to stream health:

What is the distribution of water on earth?

What are the 5 main parts of the water cycle?

Station 4: Safe Drinking Water Quality
How is water quality monitored in our town?

What is potable water?

Why is water quality important to humans?

Station 5: Physical factors #1: Turbidity, pH, nitrates, phosphates, DO
pH_____Nitrates______ Phosphates_______ Dissolved Oxygen (DO)_______ Turbidity (NTU)_____

What numbers does the pH scale range from? What is considered neutral?

What are sources of nitrates in aquatic ecosystems? Phosphates?

How do nitrates and phosphates impact aquatic ecosystems?

How does turbidity impact aquatic habitats?

Station 6: Stewardship and Restoration
Stewardship: What can landowners do to protect water quality of their stream reaches?

What is a water quality standard?

How are water quality standards mandated and regulated?

Restoration: What types of features or techniques can be used to improve streams if they are degraded?

Station 7: Physical factors #2: Temperature, Flow, Salinity
Salinity ______________ppm Water Temperature ˚C______ Streamflow _________ft^3/s

What impact do high flow rates have on a stream?

What is the relationship between water temperature and DO?

What impact does high conductivity have on a stream?

Station 8: Invertebrate Bioindicators – aquatic insects, snails, worms, crayfish
What is a macroinvertebrate bioindicator?

What macroinvertebrates are sensitive to pollution?

What macroinvertebrates are NOT sensitive to pollution?

What is your Stream Index Score?

What is your Stream Water Quality?

Why do scientists use macroinvertebrates as bioindicators?

Station 9: Wastewater Treatment
What are the basic steps involved in treating wastewater?

What are the benefits of treating wastewater?

What water quality measurements do the managers of the water treatment plant use?

Appendix D: Watershed Field Day Event Station Information

During each station, students should either fill out their data analysis worksheet throughout their time at each station, or time should be provided at the end of the station to reflect on the material presented and answer the analysis questions.

Station #1: Watershed Concepts

- **Materials:** Playdough, Poster Board, Topographic Maps of Local Watershed, Maps of rivers in your state, Enviroscape Watershed Model
- **Activity Description:** At this station, students will separate into two groups. Each group will complete a different activity (12 minutes) and then switch.
    - **Activity #1:** Watershed Modeling (12 minutes)
        - Using the Enviroscape Watershed Model, the presenter should talk students through the model and demonstrate how water flows through a watershed. The presenter should demonstrate how runoff in a watershed can carry pollutants to different water sources, and how these pollutants can spread throughout the watershed. The presenter should then lead a conversation about the best management practices to prevent this pollution. Next, the presenter should engage students in a discussion about their local watershed, defining it and discussing potential sources of pollution like they had just seen in the model. To ensure this station is hands-on, the presenter should engage students in the model, allowing them to add the "pollutants" and water to the model and referring to the model often during the discussion.
    - **Activity #2:** Build a Watershed (12 minutes)

        - At this station, the presenter should provide each student with playdough and tell them to build a geologic feature (mountain, valley). Once students have created their feature, have them all place their features on a poster board. Then the presenter should show the students a local topographic map (of your local watershed) and explain what topographic maps help us visualize, comparing it to the "map" they just created. The presenter should then lead a conversation about what a watershed is, and how the topography of the land helps determine the boundary of a watershed, how the land cover in a watershed can impact the overall health of the watershed and connecting this to the previous stations students have visited (if applicable). Lastly, the presenter should lead a discussion about the "bigger picture" using the maps of rivers in your state (and even larger scale maps such as the entire U.S.), showing where the water that passes through their local watershed flows through, until eventually it reaches the ocean.
    - Give students time at the end of the activity to answer the analysis questions on their worksheet.

Station #2: Vertebrate Bioindicators – darters, trout, salamanders

- **Materials:** Backpack Electrofisher, Nets, Waders, Large Cooler, jarred specimens of native fish
- **Activity Description:** (25 minutes) At this station, students will start by watching a demonstration of electrofishing. Here, the presenter should describe the process of

electrofishing and why it is used by scientists. Once a few fish samples have been collected, they should be placed in a large cooler for students to observe. The presenter should then lead a discussion about what a vertebrate bioindicator is, what species of fish were found in the stream during electrofishing (if needed, refer to the jarred specimens), and what the presence of these fish says about the quality of the water. The presenter should also talk about how fish are used to determine stream quality, discussing things such as age, pollution sensitivity and role in the ecosystem. Next, the presenter should ask students to look at their surroundings (near the stream bank) and make some observations. Then the presenter should lead a conversation about the biotic and abiotic factors which can affect fish survival (using the observations they just made).

- Students should fill out their data analysis worksheet as they are learning at this station.

Station #3: Riparian Zones & The Water Cycle

***The activities at this station have been modified to incorporate more "hands-on, minds-on activities, to improve student achievement of learning outcomes, based on the results of this study.**

- **Materials:** Enviroscape Watershed Model, Whiteboards, Whiteboard markers
- **Activity Description:**
    - **Activity #1: Distribution of Water on Earth & The Water Cycle (20 minutes)**
        - Students should partner with the person they are sitting beside ,and each group should be provided a whiteboard and a marker. Ask the

groups to work together with their partner to draw a pie chart representing the distribution of land vs. water on Earth. After one minute, ask students to hold up their whiteboards. The presenter should lead a discussion about the correct distribution. Next, instruct students to work together draw a pie chart representing the distribution of fresh vs. salt water on Earth. After one minute, as students to hold up their whiteboards and lead another discussion about the correct distribution. For the last whiteboard activity, the presenter should instruct students to work together to draw the water cycle in as much detail as possible on their whiteboards. Give students about 5 minutes to complete this. Once time is up, have students hold up their whiteboards and everyone take a minute to view each other's drawings. The presenter should then lead a discussion about the parts of the water cycle, having students add to, or correct their drawings during the discussion.

- **Activity #2: Riparian Zones (5 minutes)**
    - Using the Enviroscape Watershed Model, the presenter should ask a volunteer to point on the model where a riparian zone is located. The presenter should then lead a discussion about what riparian zones are and what benefits they provide streams, referring to the model and the nearby stream during the discussion.
- Give students time at the end of the activity to answer the analysis questions on their worksheet.

Station #4: Safe Drinking Water Quality

***The activities at this station have been modified to incorporate more "hands-on, minds-on activities, to improve student achievement of learning outcomes, based on the results of this study.**

- **Materials:** Two small coolers: one filled with well water, one filled with city water, Disposable Cups, Print outs of water crisis activity
- **Activity Description:** At this station, presenters should have 2 coolers set up, one filled with well water and the other filled with city water. The presenter should ask for a student volunteer, instructing the volunteer to taste each sample, not letting them know the sources for each sample. The presenter should ask the volunteer to guess which one is well water and which one is spring water. The presenter should then lead a discussion about the two main sources of water for most people, polling students about where their water at home is from. The presenter should also discuss how potable water is a finite resource, how water quality is monitored, and why water quality is important to humans. Next, the presenter should divide the students into three equal groups and provide them with the water crisis activity below. Instruct students that they are the mayor of a town which currently has a water crisis. As the mayor, it is their responsibility to find a solution to the growing water shortage. They have been provided with six options, which they must rank in order of "4-Bad idea", "3-Fair idea", "2-Pretty good idea", "1-Great idea"
    - 1. Mandatory restrictions on water use
    - 2. Find new water supplies (build a reservoir, new wells)
    - 3. Raise the price of water

- 4. Cut back/stop new developments
- 5. Encourage water conservation
- 6. Buy water from another city/state

"Elect" one student in each group to be the leader and have them share each of these options and lead a discussion with their group about the options.

Once groups have discussed and determined their plain of action, the students should reconvene as a whole for the presenter to lead a discussion about the activity, mentioning the pros and cons for each option.

- Give students time at the end of the activity to answer the analysis questions on their worksheet.

Station #5: Physical factors #1: Turbidity, pH, nitrates, phosphates, DO

- **Materials:** Water Chemistry Probe(s): YSI or Vernier with multiple probes for each parameter
- **Activity Description:** At this station, students should use a water chemistry probe(s) (Vernier or YSI) to go in the stream and collect these measurements. Prior to having students collect them, the presenter should give students a short demonstration of how to operate the equipment. Once the data has been collected and shared with students for them to record on their worksheet, the presenter should lead a discussion about the values collected, normal ranges for each parameter, what the sources are for each parameter and how these parameters can be used to determine the health of the stream.
- Data analysis worksheets should be filled out during instruction at this station

Station #6: Stewardship and Restoration (Adapted and modified from the lesson created by Dr. Saskia van de Geve)

- **Materials:** Pencils, Pens, Printer Paper (each labeled numbers 1-10 on the bottom right corner), items that represent pollution courses (see examples below)
- **Activity Description:** Divide students into groups of 2 or 3, provide each group with a pencil and one piece of numbered white paper.
  - 1. Inform students that they have just inherited a piece of riverfront property, and a million dollars. Have them draw a blueprint of the land and how they will use the money. They have one million dollars to develop their land as they wish. They can farm or ranch; build resorts, homes, factories, or parks; plant forests, log, mine – whatever they like.
  - 3. When students have completed their drawings, ask them to look in the lower right-hand corner of their property for a number. Explain that each piece is a part of the puzzle. Starting with number one, have students assemble their pieces. They will construct the stream pathway in proper order.
  - 4. Have each group describe how they developed their land and how they used water. They should identify any of their actions that polluted or added materials to the waterway. As they are describing their plan, the station presenter should provide each group with items which represent the pollution they are adding to the stream (ex: sprinkles for fertilizer, plastic toy cows, toy gas can, cocoa power for fecal matter)
  - 5. Tell students to take their item(s) and line up in the same order as their pieces of river front property. They are going to pass their pollution pieces downstream. Have them announce what kind of pollutant they are holding before they pass it on. The ones will pass their item(s) to the twos, the twos

will pass everything to the threes, and so on, until the last students are holding all the items.

- **Wrap Up:**
  - After all the items have reached the final students, discuss the activity. How did those students toward the middle or at the end of the river feel? What about their property use plans? Could a student downstream be affected by the actions of a student upstream? Could upstream users alter the water quality of those downstream?
  - Tell students to reclaim their items. Explain that the items easily identifiable as their own simulate point source pollution. Other items may be more difficult to claim, because these kinds of pollutants originated from multiple sources. Tell students these represent nonpoint source pollution.
  - When all the students have passed their pollutants down to the end of the river and you've discussed point sources and nonpoint sources, ask the students for ideas on how they could minimize the impact their activities might have on the river. Explain how a vegetated buffer can prevent nonpoint source pollutants (like gas, oil, and lawn chemicals) from washing off from parking lots and lawns every time it rains. A good vegetated buffer is wide and has a variety of different kinds of plants on it, ranging from ground covers to bushes and trees. A good buffer can do a lot to help prevent nonpoint source pollutants from reaching the river!

- Allow students time at the end to answer the questions on their analysis worksheet using the information they just learned, and time to ask questions about topics not explicitly discussed.

Station #7: Physical factors #2: Temperature, Flow, Salinity

- **Materials:** Water Chemistry Probe(s): YSI or Vernier with multiple probes for each parameter, 3 large rubber ducks or tennis balls, large rolling measuring tape, 3 meter-sticks, stopwatches, calculators, large whiteboard and marker for presenter
- **Activity Description:**
- **Activity #1: Water Chemistry:**
  - At this station, students should use a water chemistry probe(s) (Vernier or YSI) to go in the stream and collect these measurements. Prior to having students collect them, the presenter should give students a short demonstration of how to operate the equipment. Once the data has been collected and shared with students for them to record on their worksheet, the presenter should lead a discussion about the values collected, normal ranges for each parameter, what the sources are for each parameter and how these parameters can be used to determine the health of the stream.
- **Activity #2: Calculating Stream Flow**
  - Next, to calculate stream flow, the presenter should quickly explain how stream flow is calculated using width, depth and velocity measurements. (You can also use a water chemistry probe to calculate). First, two students should use the rolling measuring tape to measure the stream width from three different points along the river. Next, three students should use meter

sticks to measure the stream depth at three points along the river. Lastly, three students should be provided with a rubber duck or tennis ball. They should release the item at the same location, equally spaced out along the width of the river, while one person on the stream bank with a stopwatch is going to measure how long it takes each of the items to travel along a specified distance (5 meters). Using all of this collected data, students should return to the bank to calculate flow. The presenter should use the large whiteboard to show the students how to use the measurements collected to calculate stream flow.

- Once all measurements have been collected, the presenter should give all students time to answer the reflection questions on their worksheet, and for students to ask any questions.

Station #8: Invertebrate Bioindicators – aquatic insects, snails, worms, crayfish

- **Materials:** Kick-seine, D-net, forceps, collection jars, macroinvertebrate identification keys
- **Activity Description:** First, the presenter should begin by asking students the following questions: What an invertebrate? What does the word benthic mean? What does the prefix macro- mean? Then putting all of these together, what is a benthic macroinvertebrate? The presenter should explain why scientist use benthic macroinvertebreates to determine stream health. The presenter should explain that students are going to collect and identify benthic macroinvertebrates. First, the presenter should show students how to use the collection equipment (kick-seine and d-net) and then students should go to the stream and begin collection. Once

collections have been made, the students should bring the nets to the stream banks to place the specimens in jars for identification. The presenter should help students use the ID keys to identify their specimens. The presenter should lead a discussion about which species are tolerant to pollution, and which ones are intolerant, and how this information is used to determine water quality. Once the specimens have been identified, the presenter should help students calculate the stream index score using the collected specimens to determine the stream health.

Station #9: Wastewater Treatment

- **Materials:** microscopes, projector (for PowerPoint presentation)
- **Activity Description:** At this station, the presenter will show students a PowerPoint presentation which walks students through each step in the wastewater treatment process and why wastewater treatment is important. After the presentation, students will have the opportunity to look at microscope slides of different specimens and see other samples which the town wastewater treatment lab scientists work with daily.

Vita

Jordan Lollar English was born in Asheville, NC, to parents Rex and Becky Lollar. She graduated North Buncombe High School in Weaverville, NC, in June 2013. She then attended Appalachian State University where she obtained her Bachelor of Science in Biology (Environmental, Ecology and Evolutionary concentration) with a minor in Geology and a certification in Geographic Information Systems in August 2017. During her undergraduate career, she gained research and educational outreach experience under the guidance of Dr. Shea Tuberty. She returned to Appalachian State University in the Fall of 2017 to pursue her Secondary Education licensure through the NSF funded Noyce Scholars program and simultaneously started the Master of Science program in Biology, with a concentration in Secondary Science Education under the mentorship of Dr. Shea Tuberty. In August of 2018, she accepted a teaching position with Watauga High School. While working full time as a high school science teacher, she continued her research and coursework. She married her husband Justin English in June 2019. Upon graduating in May 2020 with a Master of Science in Biology, she plans to pursue a career in educational outreach with the consideration of pursuing a Ph.D. in the future.